

THE GEOGRAPHICAL ANALYSIS OF THE CHANGES OCCURRING IN TERKOS LAKE (ISTANBUL) AND ITS SURROUNDINGS

TERKOS GÖLÜ (İSTANBUL) VE ÇEVRESİNDE MEYDANA GELEN DEĞİŞİMİN COĞRAFİ ANALİZİ

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Abstract

This study analysis the changes occurring in Terkos Laguna Lake and its surroundings, located in northwest coasts of Turkey, by using Geographic Information Systems and Remote Sensing techniques. The land use and its changes, as well as the changes that occur in lake areas and coastline were identified in the study by conducting land classifications. It was observed in the analysis that the residential areas advance towards areas where the lake is located. A decrease in the ratio of 9.79 km² (23.78 %) took place in the area of Terkos Lake in a period of 27 years from 1987 to 2014. The coastline fell to 85.62 km² by decreasing 116.45 km (57.74 %) in this period of 27 years. The residential areas around the lake, agricultural activities, the excessive of the resources that nourish the lake, drought and vaporization proved to be effective on these changes. This situation necessitates taking measures and creating a sustainable management plan in order to prevent the occurrence of unavoidable problems in the area which meets 30 % of Istanbul's fresh water needs.

Key Words Geographic Information Systems (GIS), Remote Sensing (RS), Terkos Lake, Analysis of Change

Özet

Bu çalışmada, Coğrafi Bilgi Sistemleri ve Uzaktan Algılama teknikleri kullanılarak Türkiye'nin kuzeybatı kıyısında yer alan Terkos Lagün Gölü ve çevresinde meydana gelen değişim analiz edilmiştir. Çalışmada arazi sınıflandırmaları yapılarak arazi kullanım ve değişimleri ile göl alanı ve kıyı çizgisinde meydana gelen değişimler belirlenmiştir. Yapılan incelemede özellikle yerleşim alanlarının gölün bulunduğu alana doğru ilerlediği belirlenmiştir. Terkos Gölü alanında 1987 yılından 2014 yılına kadar geçen 27 yıllık sürede 9,79 km² (% 23,78)'luk bir oranda azalma olmuştur. Kıyı çizgisi ise 27 yıllık sürede 116,45 km azalarak (% 57,74) 85,62 km'ye düşmüştür. Bu değişimler üzerinde göl çevresindeki yerleşmeler, tarımsal faaliyetler, gölü besleyen kaynakların aşırı derecede kullanımı, kuraklık ve buharlaşma faktörleri etkili olmuştur. Bu durumun İstanbul'un % 30'luk tatlı su ihtiyacını karşılayan sahada dönüşü olmayan problemler meydana gelmemesi için, tedbir alınmasını ve sürdürülebilir bir yönetim planının oluşturulmasını gerekli kılmaktadır.

Anahtar Kelimeler: Coğrafi Bilgi Sistemleri (CBS), Uzaktan Algılama (UA), Terkos Gölü, Değişim Analizi

INTRODUCTION

Water is one of the most important elements necessary for the existence and continuity of human beings and ecological systems. The rate of fresh water is 2.5 % even though 1.4 km³ of the world is covered with water (Dirican and MusuL, 2008). However, today, the rapidly increasing population and environmental problems lead to the increase in demand for water supplies and threatened the existence of water which is one of the most important elements for the ecological quality of life. Negative problems, such as population growth and unplanned and improper land use, continue to change water sources, agricultural lands, forested areas and natural environment very quickly (Erlich, 1988, Biswas, 1997, Loucks, 2000, Taş, 2006, Özşahin, 2011). The statements, made by FAO (1994), clearly show these changes by asserting that there was no increase in forest lands in Turkey between 1983 and 1993, but there was an increase of 3.44 % in agricultural lands in the same period (Tunay and Ateşoğlu, 2004, Özdemir and Bahadır, 2010).

One of the areas, where the changes in the natural environment are most clearly seen, is the areas of Lagoon Lake. Being shallow lakes that are connected with larger body of water like the sea, lagoons are wetlands and special ecosystems that also carry great ecological significance (Kırdağlı, 1999). Coastal lagoons are transitional zones between sea-water and freshwater environments that are under the influence of both terrestrial and marine factors (Acarlı et al., 2009). However, even though there are 72 lagoons in Turkey, many of these have lost their lagoon characteristics and productivity due to reasons like draining and discharging wastes (Gözgözoğlu, 2002, Sümer and Tekşam, 2013).

Terkos Lagoon Lake and its surroundings, one of the most important water resources of Istanbul, are located in such an area that is also affected by natural environmental problems. Terkos Lake, which has a total drainage area of 776 km², precipitation area of 744 km² and a surface area of 32 km², is approximately 12 km in length and 5 km in width (Davaşlıgil, 1998). However, inability literally to bring solution to the problems experienced in the lake area and the lack of appropriate plans for land use require analyzing the changes and development in this area.

Today, techniques of Remote Sensing and Geographic Information Systems are widely used in the determination of land use and the changes in the area. These methods do not only provide convenience in the determination of change, but also in the process of monitoring (Özdemir and Akar, 2009, Kurt et al., 2011). Developments in satellite technologies with each passing day and the increase in resolutions have rendered analysis easier and more precise. Therefore, the areal change in Terkos Lake, one of the most important freshwater and wetland ecosystems of Istanbul, and the factors that influence this change were attempted to be determined in this study by using techniques of Geographic Information Systems and Remote Sensing.

STUDY AREA

Catalca district and Terkos Lake are located between 27°58' – 29°56' eastern longitude and 40°48' – 41°36' northern latitudes. Terkos Lake is situated within the boundaries of Catalca district of Istanbul province and in Terkos Basin. It is surrounded by Black Sea in the north, Arnavutköy in the east, Büyükçekmece and Silivri districts in the south and water parting line of Ergene Basin in the west (Figure 1). The lake, formed between Karaburun in the coast of Black Sea and Ormanlı villages, is one of the most significant freshwater areas of Istanbul.

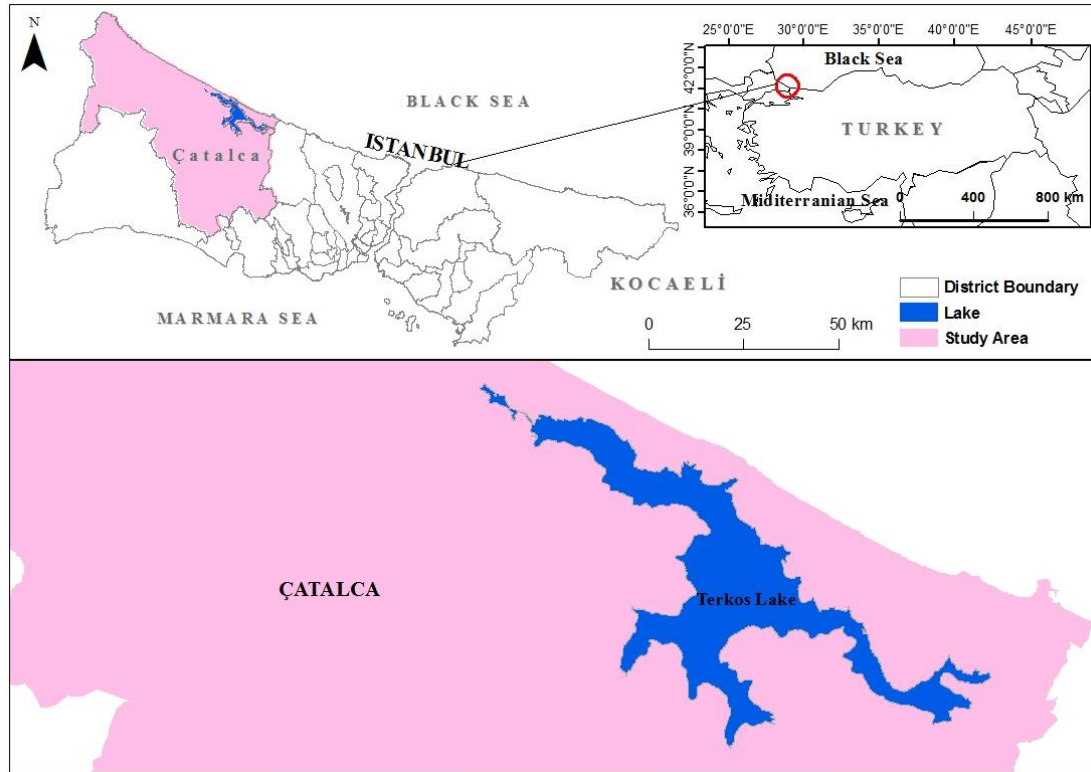


Figure 1. Study Area

MATARYEL AND METHOD

Landsat satellite images, which have spatial resolution of 30 m and belong to May of the years 1984, 2007 and 2014, and topographic map sheets of 1/25.000 in scale were used in this study that analysis the changes occurring in Terkos Lake and its surroundings. The reason why the satellite images of the same month were preferred was because it is easier to make comparisons on images with same features. The analysis and verification of the images in studies of change analysis allow data to be recorded correctly (Townshend et al., 1992, Dai and Khorram, 1998, Stow, 1999, Verbyla and Boles, 2000, Carvalho et al., 2001, Stow and Chen 2002). The image processing analyses of this study were carried out by using Erdas Imagine 10 software of Remote Sensing (RS) and ArcGis 10 software of Geographic Information Systems (GIS) since the change analyses provide more accurate results. However, information on fieldwork, and changes as well as land use the lake shore were collected since the impact of geographic factors should not be overlooked (Jensen 1996, Weber, 2001, Kurt, 2013, Kurt et al., 2010)

The classification of satellite images was also analyzed in accordance with maximum likelihood – controlled classification method by using Erdas Imagine software (Li and Ye, 1998, Akın, 2007, Goodchild et al., 1996, Woodcock et al., 2001, Reis and Yomralıoğlu, 2003, Alparslan et al., 2003, Ekinci and Ekinci, 2006, Demirci et al., 2009, Kurt et al. 2010, Özşahin, 2011). The recode process was carried out by combining every signature equivalences of data obtained as a result of the classification. Thus, the image data classes have been identified. The data, obtained in Erdas software after these processes, were converted from raster format to vector format in ArcGis software. Data in vector format were corrected by mixed classes editing method in the editing process after being controlled from the reference data. Outcome data was obtained as a

result of these processes. The general classes used in classification are: residential area, agricultural fields, vacant areas, bush/grass, lake/water, forest and clouds.

Principal Component Analysis (PCA) technique was used in the determination of coastal line of the selected years since it helps to distinguish the difference between water and land. PCA is the technique of creating a new image after removing the relationship between multispectral images and reducing the image in numerous bands to the desired number of bands (Munyati, 2004, Mausel, 2004, Almutairi and Warner, 2010). This is a useful method because it collects a significant amount of information in multispectral data and reducing the correlation between imaging bands. Principal Component Analysis (PCA) is a method preferred in image compression, image enhancement, change detection and in reducing the number of bands before classification (Loughlin, 1991, Akça and Doğan, 2002, Alparslan et al., 2004, Munyati, 2004). Thematic maps (TM), created as a result, were again transferred to Geographical Information Systems environment by converting raster data into vector data. Coastal lines and maps were created as a result of the analysis conducted on the obtained new images.

General Geographical Features of Terkos Lake and Its Surroundings

Terkos Lake is a coastal set lagoon separated from the Black Sea by sand dunes whose width ranges from 250 m to 5 km and whose average width is 2 km. It was formed by the creation of a bay as a result of the advancement of the waters of Black Sea, which rose due to Flandrian transgression, towards the land and the conversion of this bay into a lake following its disconnection from the sea in time through a coastal levee. Another factor that contributes to the formation of this lake is the enclosure of the mouth of Istranca Creek, which extends parallel to the coast of the Black Sea, by an alluvial set. Terkos sand dunes were formed in this section between Terkos Lake and the Black Sea. Sand dune fields start 25 km from the west of Bosphorus and span in an area of 30 km along the coast of Black (Köken, 1991, Aygün, 1994, Baylan and Karadeniz, 2006). Terkos sand dunes, which represent the biggest and most important sand systems located nearby Istanbul, has an international significance due to its inclusion of endemic plant species for the region (Byfield and Özhatay, 1993). The surroundings of Terkos Lake were identified in 1999 as one of the 100 “hot spots” in Europe that is most valuable in terms of biodiversity and that needs to be urgently protected within “Gift for the World” Project carried out by the co-operation between World Wildlife Foundation (WWF) and the Ministry of Environment and Forestry (Anonymous, 2002). Therefore, the lake and its surroundings have the quality to serve the environment and plant analysis type of ecological tourism (TMMOB, 2014).

There are undulating plains and high steep hills in the surroundings of Terkos Lake whose heights increase westward. The surroundings of the lake, which was formed 100-150 m in height and on the edge of this hilly area in the Black Sea coast line, have less rugged morphological structure (Akşiyat et al., 1990, Barga vd., 1995). A part of the coastal line between the Lake and Black Sea is steep-cliffed and a part of it is covered with beaches. The lands formed in the surroundings of the lake have erosion-slanted structural features (Eruz et al., 1995). Terkos Lake, being rich in terms of feeding rivers, has fresh-water characteristics despite its proximity to the Black Sea. Istranca Creek is the stream that carries the maximum amount of water to the lake (Aygün, 1994, Baki, 1997).

The geological foundation of the lake’s surroundings is composed of metamorphic rocks of the Paleozoic and Mesozoic era. The cover rocks, young sediments and Ergene group in the upper part can be found on metamorphic rocks. The limited areas on the bottom of rivers that pour into the lake are covered with the current Quaternary alluvium (Akşiyat et al., 1990,

Bargu et al., 1995). Geological units in the lake's surroundings are Eocene-aged Kırklareli, Miocene-aged Ergene Formation, Pliocene-aged Belgrade Formation, alluviums and sand dunes (Baki, 1997). These are also the units that mainly carry the groundwater. The rocks located in the water section that limits the Terkos Basin are generally impermeable or less permeable. This prevents the water exchange with neighboring basins. The conclusion that no water leakage from the lake into the Black Sea would be possible can be reached due to width and geological structure of sand dunes in some regions between the Black Sea and the lake (Bargu et al. 1995). However, it was discovered that the coastal strip, which separates the lake from the Black Sea, is dangerously narrowed because of unauthorized sand removal from the area and erosion (Özdemir, E., 2004, Maktav et al., 2002).

RESULTS

There has been a significant rate of reduction in the area of Terkos Lake according to the estimates conducted by satellite images and topographic sheets. There has been an areal reduction of 9.79 km² (23.78 %) in the period of 27 years between 1987 and 2014. While the surface area of the lake was approximately 38.63 km² (41.16 km² including the swamp) in 1987, this area was decreased to 32.67 km² in 2007. An areal change of 8.49 km² and 20.62 % has taken place in the lake within the period of 20 years. There has been a reduction of 1.3 km² and 3.97 % in the lake area between 2007 and 2014 which was 32.67 km² in 2007. The coastal line was also reduced to 85.62 km² after a decrease of 116.45 km (57.74 %) in the period of 27 years (Tables 1 and 2, Figures 2 and 3).

Table 1. Change in the Area of Terkos Lake by Years

1987 (km ²)	1987-2007 Change (km ²)	1987-2007 Change (%)	2007 (km ²)	2007-2014 Change (km ²)	2007-2014 Change (%)	2014 (km ²)	1987-2014 Change (km ²)	1987-2014 Change (%)
201,66	97,83	48,51	103,83	18,21	17,53	85,62	116,45	57,74

Table 2. Change in the Coastline of Terkos Lake by Years

1987 (km ²)	1987-2007 Change (km ²)	1987-2007 Change (%)	2007 (km ²)	2007-2014 Change (km ²)	2007-2014 Change (%)	2014 (km ²)	1987-2014 Change (km ²)	1987-2014 Change (%)
41,16	8,49	20,62	32,67	1,3	3,97	31,37	9,79	23,78

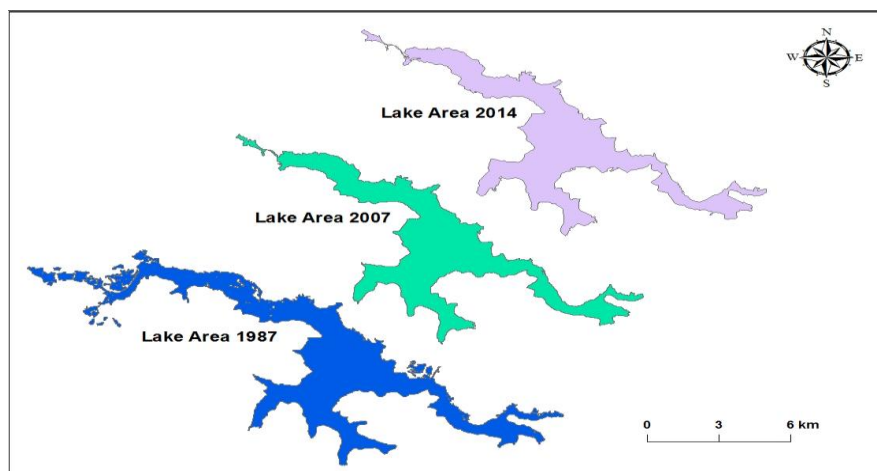


Figure 2. Area Change in the Area of Terkos Lake by Years

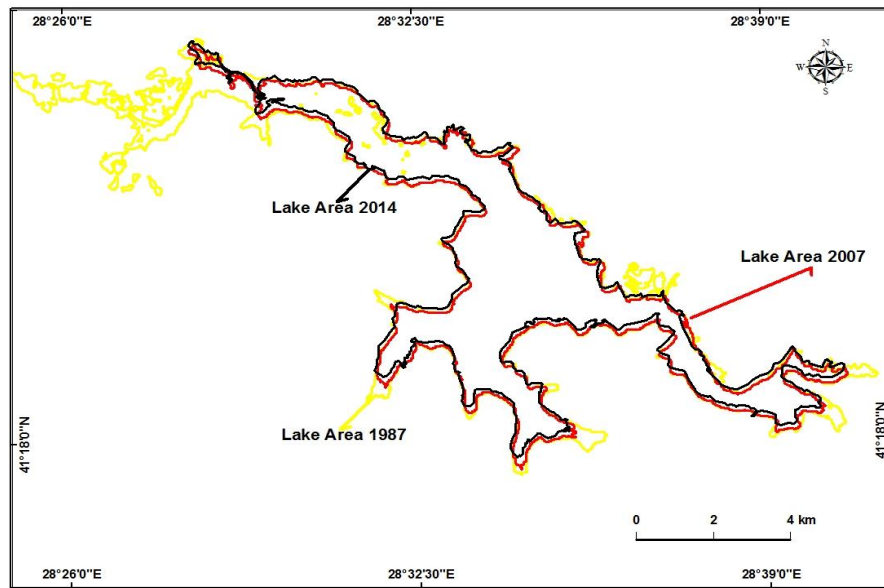


Figure 3. Change of the Coastline in the Coast of Terkos Lake by Years

One of the main reasons for this change that occurred in Terkos Lake from 1987 up to the present is the human factor including the agricultural activities. The excessive use of sources that are feeding the lake due to human activities has also been effective in reduction of the lake area. Taking water from the lake to be used in agricultural activities carried out in the surroundings of the lake leads to an increase in intensive usage. The change in land use seen in the surroundings of the lake within the period of 20 years between 1987 and 2007 clearly demonstrates this change. The settlements, which were 98.25 km² in 1987, reached 106.82 km² in 2007. This also led to the intensive use of sources that are feeding the lake. Housing around the lake is seen to increase when compared with images of 1987, 2007 and 2014 as well as the land classes (Table 3, Figure 4).

Table 3. Change in Land Use in Catalca district

Class	1987 (km ²)	%	2007 (km ²)	%	Change (km ²)	Change (%)
Residential Areas	98,25	7,24	106,82	7,87	8,57	8,72
Agricultural Areas	191,71	14,13	245,76	18,11	54,05	28,19
Forest	551,32	40,65	432,53	31,88	118,79	21,54
Bush/Grassland	410,16	30,24	471,76	34,7	61,6	15,01
Bare Soil	57,35	4,2	62,23	4,58	4,88	8,5
Water/Lake	37,49	2,7	37,53	2,7	0,04	0,1
Cloud	9,94	0,73	-	-	-	-
Total	1356,2	-	1356,5	-	-	-

The use of groundwater and surface water resources around Terkos Lake as drinking water and useable water, mainly in agriculture, becomes effective in the change occurring on the surface of the lake. A large increase of 54.06 km² (28.19 %) in the agricultural areas around the lake from 1987 to 2007 also reveals this predicament. The agricultural lands, which had a figure of 191.71 km² in 1987, have increased to 245.76 km² in 2007 (Table 3, Figure 4). The use of the lake for irrigation purposes (Photo 1) negatively affects the flow of the sources and leads to a decrease in water level. Since Terkos Lake is located at a distance of 2.5 km to the project area

of the 3rd Airport, a greater rate of decrease in water level is expected to be seen as a result of construction works which will cause some streams that feed Terkos Lake basin, with a total water collection area of 736.km² and water area of 39 km², to get disconnected with the lake (TMMOB, 2014, Photo 1).

Catalca district of Istanbul is one of the land classes with high rates of forestry and scrublands. Especially in 1987, the mountainous areas in the north and south of the basin were covered with forests and, in some places, forests went down up to the eastern shore of the basin. Nowadays, forest areas are widely seen in mountainous areas in the western and southern parts of the lake. The hills, which are on the landward side of the lake and rise up to approximately 100 meters, are generally covered with meadows and a community of forest plants (Byfield and Özhatay, 1993). However, there was a decrease in forests and bushy areas in recent years due to the increase in settlements in these regions (Table 3, Figure 4). While 40.65 % (551,32 km²) of 1356. km² land were covered with forests in 1987, this rate came down to 31.88 km² in 2007. In 1987, the bushy lands, with the area of 410.16 km², covered 30.24 % of the total area of 1356.2 km² (Table 3). In 2007, this land class has decreased by 34.7 %. Increase in settlement and construction especially in Terkos Lake and its surroundings as well as on the Black Sea coast of Catalca district has been effective in this decline.

Terkos Lake is the second largest area that meets with about 30 % (142.000.000 m³) of Istanbul's water needs. Therefore, the Terkos Lake Dam, built in this area in 1983 and being developed, continues to provide service today (Bayram et al., 2013, Baki, 1997). However, this area is under the pressure of approximately 30.000 people who live in 18 residential areas of Catalca district (Table 4). There is an increase in seasonal population of the Lake and its surroundings both because they are located on the sea coast and forestry fields in the area offer recreation facilities (Baylan and Karadeniz, 2006).

The lake pollution continues to increase with each passing day due to increase in population and construction around the lake in recent years. Therefore, lake water is reported to have dropped from the second class quality drinking water to the third class quality (Baylan and Karadeniz 2006). The pollution, caused by the residential areas around Terkos Lake, causes serious damage in ecological system of the lake as seen in some wetlands in Turkey (Altınsaçlı and Griffiths, 2001, Arı 2002, Tağıl, 2007). TMMOB Istanbul Branch of Environmental Engineers Association has also identified that the waters of Terkos Lake significantly reduced and the pressures of pollution increasingly continue as a result of the activities carried out in the basin (TMMOB, 2014, Photo 1).



Photo 1. Pollution in Terkos Lake

The contraction of the lake area, together with the contraction of swamps in the locality, contributed to the increase in the class of vacant lands. This class of land consists of rocky and swampy areas with change rate of 4.88 km² (4.2%) located mostly in coastal areas and inland in addition to residential, agricultural, forestry and bushy lands in the research area (Table 3 and Figure 4).

The class land, which was referred to as water in 1987, is 37.49 km². The ratio of water class in 2007 is 37.53 km². This is because Catalca has also taken in a portion of the northern parts of Büyükçekmece and Küçükçekmece lakes (Table 3 and Figure 4).

Table 4. Distribution of the Population in the Surroundings of Terkos Lake by Years

Residential Areas	1985	2007	2013
Karaburun	544	1029	1.354
Balaban	470	324	397
Yazlık	418	390	378
Örencik	774	775	805
Hisarbeyli	464	446	403
Ormanlı	1158	1107	1.115
Celepköy	395	270	259
Terkos (Durusu)	2213	2.299	1826
Çatalca (Total)	117.380	27.807	65.811

Source: www.tuik.gov.tr

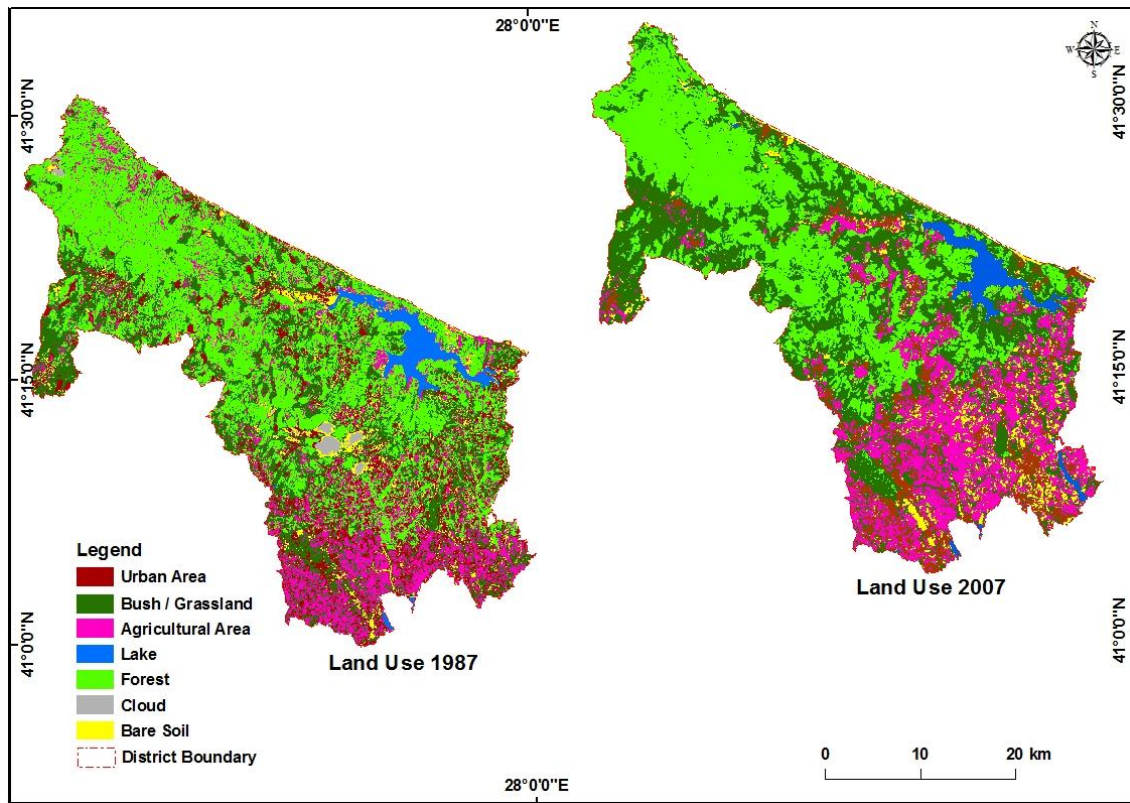


Figure 4. Change in Land Use in Catalca District

One of the factors affecting the lake area is also the changes experienced in climatic conditions. Increase in temperatures in Istanbul during the period of four months started from the month of June and continued until October as well as inadequacy of rainfalls caused a significant amount water to evaporate from the surface of the lake. This causes the water level in the lake to reduce further with each passing year (Table 5).

Tablo 5: Monthly Average Temperature (°C) and Monthly Total Rainfall (mm)

Settlements	Yıl	1	2	3	4	5	6	7	8	9	10	11	12
İstanbul (°C)	1987	6.4	7.7	4.7	10.6	16.5	21.7	24.5	22.6	21.0	14.9	12.8	7.7
İstanbul (°C)	2007	8.5	-	-	11.8	20.1	24.3	25.4	25.8	20.7	16.8	-	6.9
İstanbul (°C)	2010	7.0	-	9.0	13.7	19.4	22.8	25.8	27.8	-	15.2	15.8	10.4
İstanbul (mm)	1987	111.4	27.1	114.1	33.6	29.5	25.3	73.6	44.0	0.3	99.5	74.8	144.2
İstanbul (mm)	2007	43.1	51.0	78.0	20.7	11.2	3.1	38.4	0.0	100.5	112.2	51.1	94.5
İstanbul (mm)	2010	185.5	140.7	69.7	47.5	13.0	104.2	42.6	1.8	15.9	278.4	14.8	161.9

Source: General Directorate of Meteorology

CONCLUSIONS

In the course of time, there has been a significant change in the Terkos Lake area which is one of the most important wetlands in Istanbul. A decrease of 9.79 km² (23.78 %) has taken place in the area of Terkos Lake in the period of 27 years from 1987 until 2014. The coastal line has fallen to 85.62 km² due to a decrease of 116.45 km² (57.74 %) in 27 year-period. While the lake area had been 41.16 km² in 1987, this first dropped to 32.67 km² in 2007 and to 31.37 km² in 2014.

Settlements and agricultural activities around the lake, excessive use of resources that feed the lake, drought and evaporation have been effective on these changes. The change primarily led to a significant amount of decrease in the lake area. In addition to this, human activities, carried out around the lake, have caused damage primarily to ecosystem. Pollution in lake water and around the lake has increased significantly. Living organism in the lake has been under threat. The following measures should be taken in order this situation not to cause irreversible problems in an area that meets the 30 % of Istanbul's fresh water needs: to increase the impact of settlements on the lake sources more coherently with the environment, to adopt a careful and systematic water usage policy especially in the months of summer when water shortage is experienced the most, to prepare and to implement plans that will make better use of water potentials, to pursue a policy harmonious with nature within the framework of cooperation with the local community about the contamination caused by the settlements around the lake, to create a sustainable management plan and to prevent all kinds of destruction by preserving northern forests that feed all the wetlands of Istanbul, especially Terkos Lake.

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